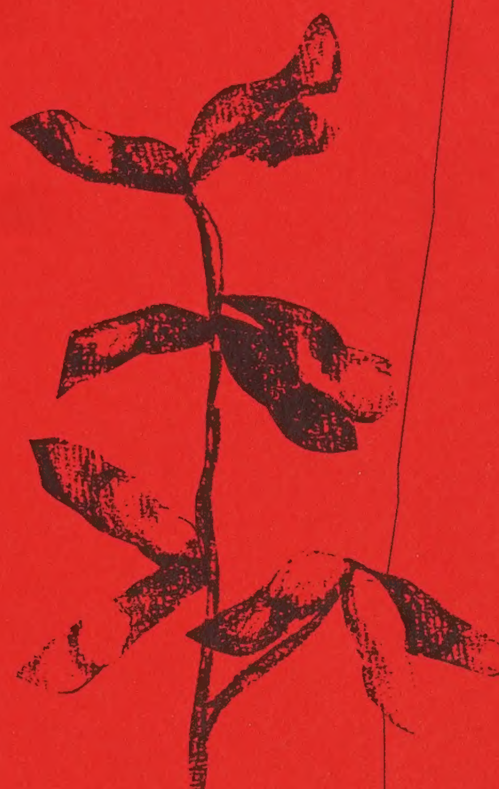
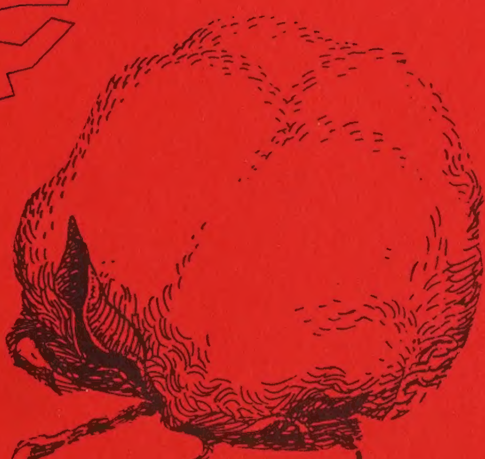
SOUTHERN INSECT MANAGEMENT LABORATORY USDA/ARS

STONEVILLE, MISSISSIPPI





Annual Report on Progress (CY 1993) and Plans (CY 1994)

CONTENTS

I. INTRODUCTION

This report summarizes progress made on various research objectives in 1993 and presents plans for 1994.

Many of the results are preliminary and others are being released through established channels. Therefore, this report is not intended for publication and should not be referred to in literature citations.

The intent of this report is to give the reader an overview of Southern Insect Management Laboratory (SIML) research activities. These activities (progress and plans) address the laboratory and unit missions (listed on pages 5-8). To accomplish the mission, the Laboratory is divided into one unit at Stoneville (Southern Insect Management Research Unit (SIMRU)) and one unit at Mississippi State (Insect Rearing Research Unit (IRRU)) which is housed in the R. T. Gast Rearing Laboratory.

SIML activities are centered around seven research thrusts, which reflect present CRIS work units. These are:

(1) Biological and genetic control and area-wide management of crop insect pests, emphasizing *Heliothis/Helicoverpa*;

(2) Population ecology of insect pests for integrated control/management systems;

(3) Biology, ecology, behavior, and biological control of plant bugs, cotton aphids, and sweetpotato whitefly;

(4) Strategies for managing crop insects, emphasizing the cotton agroecosystem and pesticide effectiveness;

(5) Integrated control of pecan pests;

(6) Host plant resistance in soybean pests; and

(7) Mass propagation technology for the boll weevil and *Heliothis/Helicoverpa*, and their parasites.

The first through sixth areas are researched by the SIMRU and the seventh by the IRRU.

This report is divided into four sections:

(1) Report on research progress in CY 1993;

(2) List of publications including those in press and accepted for publication;

(3) Other indicators of progress such as presentations and papers in manuscript; and

(4) Plans for CY 1994.

In each section, items are arranged by researcher (in alphabetical order of lead scientist; the name of lead scientist and cooperating and/or collaborating researchers are provided for each item). If the reader has questions pertaining to the item, he/she should contact the individual scientist, research leader, or laboratory director.

II. MISSION STATEMENTS AND STAFF

SOUTHERN INSECT MANAGEMENT LABORATORY
ARS/USDA, Mid South Area
Stoneville, Mississippi 38776
Telephone: Comm. 601-686-5231
FTS: 700-497-2231
FAX: 601-686-5421

OFFICE OF LABORATORY DIRECTOR

MISSION:

The mission of the Southern Insect Management Laboratory is to conduct fundamental research on the biology, ecology, and rearing of field crop and pecan insect pests and their natural enemies; develop innovative biological, genetic, cultural, and chemical methods for suppressing insect pests; and integrate this knowledge into insect management systems, with emphasis on area-wide methods for *Heliothis/Helicoverpa.* A goal of this laboratory is to develop new and improved insect pest suppression strategies, including improvements in pesticide effectiveness, for population management approaches to improve crop production efficiency. Exotic organisms are received and cleared through the Stoneville Research Quarantine Facility for biological control of insects and weeds. Exotic predators and parasites are released and evaluated for establishment on field crop insect pests.

ARS PERSONNEL:

D. D. Hardee, Laboratory Director
- T. G. Burton, Secretary OA
  - L. E. Taylor, Office Automation Assistant
- W. W. Bryan, Quarantine Officer (on University leave)
- F. M. Williams, Acting Quarantine Officer
- G. G. Hartley, Entomologist (Insect Rearing)
  - H. E. Winters, Biological Technician (Insect Rearing)
  - R. L. Ford, Insect Production Worker
  - G. J. Patterson, Insect Production Worker
- J. D. Warren, Engineering Technician (Shop)

SOUTHERN INSECT MANAGEMENT RESEARCH UNIT

MISSION:

To develop new knowledge on the biology of field crop insects for development of new and improved control principles and to establish fundamental principles for encouraging and using natural enemies more effectively. To develop and integrate insect suppression strategies into field crop and pecan systems that minimize the cost of plant protection, yet are ecologically acceptable. Specifically:

1. Elucidate the efficacy of indigenous predators and parasites, particularly those attacking the bollworm, *Helicoverpa zea*, and tobacco budworm, *Heliothis virescens*.

2. Research and develop methods for augmenting parasite populations in management of insect pests of field crops, particularly use of *Microplitis croceipes* and other parasitoids for control of *Heliothis/Helicoverpa*.

3. Develop new knowledge on biology and behavior of *Heliothis/Helicoverpa* spp., initially emphasizing genetic characterization of *Helicoverpa* for establishment of a bollworm sterile hybrid and utilization of the *Heliothis* sterile hybrid and entomopathogenic viruses in area-wide management.

4. Conduct basic biological and ecological research on plant bugs, particularly the tarnished plant bug, *Lygus lineolaris*, aphids, particularly the cotton aphid, *Aphis gossypii*, and the sweetpotato whitefly, *Bemesia tabaci*.

5. Develop monitoring and predictive technology through quantitative population ecology for field crop insect pests, particularly bollworm/budworm, tarnished plant bug, and cotton aphid.

6. Assess the role of early season host plants in the buildup of *Heliothis/Helicoverpa* and tarnished plant bug populations and devise new and innovative tactics for suppressing these populations.

7. Develop chemical/biorational control tactics for use in integrated systems.

8. Develop chemical, biological, and other nonchemical methods for control of insect and mite pests of pecans. Evaluate selections and native pecans for yield and adaptability to the mid-south.

9. Locate, develop, and evaluate soybean cultivars resistant to insects.

ARS PERSONNEL:

D. D. Hardee, Research Leader, Laboratory Director
(Supervisory Research Entomologist)

M. R. Bell, Research Entomologist
R. W. Hoagland, Biological Technician

G. W. Elzen, Research Entomologist
L. C. Adams, Biological Technician

D. E. Hendricks, Research Entomologist
D. W. Hubbard, Biological Technician

L. Lambert, Research Entomologist
W. L. Solomon, Biological Technician

M. L. Laster, Research Entomologist
S. B. Ginn, Biological Technician

W. P. Scott, Research Entomologist
D. A. Adams, Biological Technician

M. T. Smith, Research Entomologist
M. C. Russell, Biological Technician

G. L. Snodgrass, Research Entomologist
R. A. Drake, Biological Technician

P. G. Tillman, Research Entomologist
Vacancy, Biological Technician

A. A. Weathersbee, Research Entomologist (Research Associate)

INSECT REARING RESEARCH UNIT

MISSION:

The goal of this management unit, located at Mississippi State, Mississippi, is to develop science and technology of mass propagation, storage, transfer, and release of cotton insects emphasizing the boll weevil and *Heliothis, Helicoverpa*, and their parasitoids, especially *Microplitis croceipes* (Cresson). Specifically:

1. Research is directed toward establishment of a cost effective propagation program capable of producing the quantity and quality of insects required to support field evaluation needs.

2. Initial research emphasis is placed on boll weevil production, automation of *Heliothis/Helicoverpa* and parasite rearing, establishment of quality control standards, establishment of standards for shipping and releasing insects, and evaluation of new rearing methods.

ARS PERSONNEL:

D. D. Hardee, Research Leader/Laboratory Director
(Supervisory Research Entomologist)

J. L. Roberson, Supervisory Entomologist
T. L. Blair, Insect Production Worker
E. M. Griffin, Biological Technician
D. K. Harsh, Engineering Technician
O. L. Malone, Biological Laboratory Technician
G. G. McCain, Secretary
C. Tate, Insect Production Worker
M. Tate, Insect Production Worker

III. SUMMARY OF RESEARCH PROGRESS FOR CALENDAR YEAR 1993

A. Narrative

1. In-House

An early-season cage test was conducted to determine the comparative effectiveness of two entomopathogenic viruses, viral doses and spray adjuvants, and an entomopathogenic nematode in reducing the emergence of tobacco budworm and cotton bollworm moths from early season hosts. The pathogens were sprayed by hand on caged weeds consisting primarily of wild geranium. Results of the study indicated that a virus having a broad host range reduced emergence equal to that caused by *Baculovirus heliothis*. Application of the nematode on foliage at a rate of 200k/square meter did not reduce the emergence as well as the normal rate of virus. (M. R. Bell)

The new baculovirus having a broad host range (celery looper isolate) was field tested in small plot studies to determine its effectiveness against tobacco budworms, cotton bollworms, and beet armyworms. Although two field trials were set up, each with ten treatments and four replicates, damaging populations of tobacco budworms and cotton bollworms failed to occur resulting in collection of few data; however, very high populations of beet armyworms occurred in one test where the relative effectiveness of a baculovirus isolated from beet armyworms was compared to two other baculoviruses known to infect armyworms. Results of this field trial indicated the armyworm virus was superior to the other viruses tested in producing efficacious control, and further testing of this new virus is needed. (M. R. Bell)

Field trials were conducted where entomopathogenic nematodes were sprayed on soil to determine their effect on emergence of tobacco budworms from the soil after larval development. Those tests showed that a single application of the nematode under cotton in mid-July resulted in reduced tobacco budworm emergence of ca. 50% or more through August. Nematodes placed in the soil in June were shown to persist for at least 21 days, reducing the emergence of tobacco budworm moths by up to 75%. At this time however, the cost of the nematodes is considered prohibitive for use in large area management of pests. (M. R. Bell)

Virus production trials were conducted and a virus production facility set up and organized to mass produce baculovirus using newly developed semi-automated procedures. (M. R. Bell)

Chemical insecticides and biologicals were evaluated for control of several pest species with several bioassays in the laboratory and in replicated small plots. Pirate insecticide killed 100% of field collected beet armyworms treated with the spray table bioassay. Lorsban was significantly more effective than several chemicals except Pirate. Possible resistance in beet armyworms to other OP's was detected. Various mixtures, including synergists, are being tested on beet armyworms. (G. W. Elzen)

NTN 33893 (imidacloprid) was as effective as Cygon or Monitor against tarnished plant bugs in small plots. (G. W. Elzen, G. L. Snodgrass)

Resistance levels in tobacco budworms collected in Washington County were evaluated with the spray table bioassay. High levels of resistance were present for cypermethrin, thiodicarb, endosulfan, and methomyl (July and August only). Resistance levels were lowest in profenofos. However, a significant increase in resistance to profenofos was found in August. Pyrethroid resistance in a May collection was not synergizable (spray table and topical bioassays). Tests are continuing on other generations to determine if changes occur throughout the season. (G. W. Elzen)

An extensive evaluation of traps, lures, and killing strips for boll weevils showed that (1) the Consep trap (old Hardee trap) was equal to the Hercon trap in capturing weevils, (2) the Consep lure was about 60% as effective as the Hercon lure in attracting boll weevils, and (3) a DDVP killing strip was equal to the Hercon killing strip in killing boll weevils before they escaped from traps. (D. D. Hardee)

Planting date and insecticide treatments were variables in a test designed to show (1) which insecticide (capture, curacron, larvin, methyl thiodan) produced survivors most resistant to commonly used aphicides (capture, methyl thiodan), and (2) whether or not four applications of these chemicals (July 12, 19, 26, August 2) for aphids affected yield when compared to an untreated check if all other insects remained equal. Preliminary analyses of data show: (1) that aphid numbers peaked during the second week of July, ± July 15); (2) that numbers built up faster on cotton planted June

2 than cotton planted on May 21, but also declined faster, presumably to fungal attack; (3) that curacron and capture reduced aphid numbers by 50% and 60%, respectively, after the first application in the older cotton but were ineffective in the younger cotton; (4) there were no appreciable differences in resistance of aphids collected from various treatments; (5) there were no apparent differences in yield; and (6) aphids in late season from all treatments were less susceptible in laboratory dip tests to thiodan than capture. (D. D. Hardee)

A laboratory study was conducted on *Microplitis croceipes* to determine if the age of the parasitoid, when initially allowed to oviposit, influences parasitization of the host, preference for host (*Helicoverpa zea*) instar, adult progeny emergence, or progeny sex ratio. Third and fourth instar *H. zea* were exposed to three different age ranges of mated female *M. croceipes*. The ages of the parasitoids were: 3 to 5 d, 6 to 8 d, and 12 to 15 d. Oviposition was evaluated by exposing 10 third and 10 fourth instar *H. zea* to one mated female wasp in a 15 X 100 mm petri dish. Females were aspirated out of the mating cages and into the petri dishes containing the 10 larvae. Once all the larvae were stung, they were placed individually in 30-ml plastic cups containing Nutrisoy/wheat germ artificial diet. The tests were replicated five times for each age group and instar combination. Results of the study showed that of the age ranges tested, *M. croceipes* will parasitize third and fourth instars of *H. zea* equally across those ranges. However, the youngest and oldest parasitoids tested produced more males in third instar hosts. The highest number of males was in the oldest group, third instar. This may indicate lowered effectiveness of mating in older females that had not previously oviposited. The oldest group and (third instar) hosts, also had the highest numbers entering diapause under these rearing conditions. Overall, the 6 to 8 d parasitoids, with third instar hosts, gave the highest percentage adult emergence (47.5 $\pm$ 14%; X $\pm$ SD), a significant difference ($P < 0.05$) in the percentage of females produced (79%), and a significantly lower ($P < 0.05$) percentage (4.5 $\pm$ 6%) of the wasps entering diapause during the test period. This indicated that 6-8 d mated female *M. croceipes* may yield better results when used in rearing and field release programs where third and early fourth instar *H. zea* infestations occur. (W. W. Harrison-Bryan)

Laboratory studies were made to determine the location of *M. croceipes* cocoons in the soil after the parasitoid has been carried into the soil in the body of their hosts. To determine average depth bored by corn earworm parasitized by *M. croceipes*, 60 non-parasitized and 60 parasitized larvae were tested in four soil types: sandy loam, sand, potting soil, and clay. Third instars of both groups were placed individually on artificial diet in 30-ml clear plastic cups. Cups were inverted over the diet, thereby containing the larvae but yet allowing observation of larval activity. After 10 days the pots were excavated, and parasitoid cocoons, host pupae, live host larvae, or dead host larvae were located. A second laboratory test duplicated the first part except the parasitoid and host adults were allowed to emerge from the soils. The tests were replicated 15 times. Results from the laboratory showed the average distance bored in the four soil types by the parasitized and unparasitized larvae was 3.5-cm. Among parasitized larvae there were no significant differences between soil types. There was a significant difference in the distance bored in the sandy loam by unparasitized larvae, as opposed to the other three soils. In the emergence of the parasitoid and the host from the soils there was no significant difference in emergence of the adult host from soils types. There was a significant difference between the soil types in parasitoid adult emergence. The parasitoid had significantly lower emergence from clay and sand than from the other two soils. (W. W. Harrison-Bryan)

A greenhouse study was conducted using 24 *M. croceipes* parasitized and 24 non-parasitized *H. zea* larvae that were allowed to feed on potted cotton plants, drop onto the soil, and bore in a more normal fashion. Two soil types were used for this portion of the test: a sandy loam mix and a potting soil mixture. The 48 third instar larvae (parasitized and unparasitized) were randomly placed on potted cotton plants in the greenhouse. Plants were caged in 61 x 19.6-cm 100 mesh screen wire chimney cages which were designed to fit into 20.3-cm plastic pots. Plants were monitored daily and results recorded for larval feeding, dropping onto the soil, and boring into the soil. The test was replicated 12 times. There was no significant difference between soil type in mean distance bored by unparasitized or parasitized *H. zea* in the greenhouse studies. In the sandy loam soil mix, the unparasitized larvae had 4.4-cm and the parasitized larvae averaged a significantly less 1.4-cm. (W. W. Harrison-Bryan)

A survey was conducted to determine 1) the early season wild or cultivated host plants utilized by *H. zea* in Virginia, 2) the presence of *M. croceipes* on early season *H. zea* before its establishment in field corn, 3) what other parasitoids are associated with *H. zea* during the early season, 4) the abundance of first or early season host plants, and 5) the size of the early season host and parasitoid population. Plants known to be early season host of *H. zea* from studies done in Mississippi and other southeastern states were located in 13 counties in eastern Virginia and surveyed for presence of *H. zea* larvae. Plants surveyed were: Red clover (*Trifolium pratense*), Crimson clover (*Trifolium incarnatum*), Bighop clover (*Trifolium procumbens*), White clover (*Trifolium repens*), Whorl stage corn (*Zea mays*), Alfalfa (*Medicago sativa*), Peanut (*Arachis hypogaea*), and Vetch (*Vicia sativa*). Results are not complete but the largest number of *H. zea* larvae located was on red clover. A sweep net was used for sampling the cover crops. A sample consisted of five sets of 15 sweeps. This was replicated five times for each location sampled. Corn fields were sampled by making a triangular transect across each field. Individual corn plants were examined for larvae along the transect and collected when located. Larvae were placed in labeled small plastic bags and transferred to the laboratory in a cooler. Larvae were identified and observed for parasitism, host pupation, or mortality. Pheromone and light traps were used as indicators of adult and potential larval activity. (W. W. Harrison-Bryan)

Greenhouse studies began on the burrowing activities of *M. croceipes* parasitized and non-parasitized *H. zea* larvae. The tests will be done with three different soil types: 1) delta sandy loam, 2) coastal plain sandy loam, and 3) coastal plain loamy sand. Evaluation has not been completed. (W. W. Harrison-Bryan)

Field studies were conducted to determine how tillage practices affected cocoon distribution and survival in the soil. Field tests were conducted at Virginia Polytechnic Institute and State University, Tidewater Agricultural Experiment Station, Suffolk, Virginia. A 22.8-m x 64-m section of land divided into three 12.2-m plots with 9.1-m alleys, was used for the test. The first phase of the field test involved burying cocoons that would be excavated to determine the effect of tillage practices. Because the normal off-white color of *M. croceipes* cocoons is similar to the color of the field debris and leaf clutter, the cocoons were painted with a luminescent orange spray paint making them easier to locate. The cocoons were placed using a wooden 61-cm frame. The frame

was divided into 25 intersections and one cocoon was planted at the site of each intersection. A 20 penney nail attached to a forester's digging tool and marked at the correct depth was used to make chambers for the cocoons. Each plot was planted with 25 *M. croceipes* cocoons. The test had six treatments with three replicates each. The three broad treatments used were: (1) no tillage (2" no till planter); (2) minimum tillage (4" disc and 2" planter); and (3) full tillage (36" row center, 4" disc, 10" moldboard plower, 4" disc, and 3" land conditioner). After treatments were applied, the cocoons were excavated and depth measured. The second phase had cocoons buried and left covered with a fine mesh cubic meter sized cage over the winter to determine early season emergence times. Results showed the no-tillage systems had no disruption of cocoons. Minimum and full tillage systems placed 80% of the cocoons outside the range where the average cocoon location (3.5-cm) would fall. (W. W. Harrison-Bryan, D. A. Herbert)

The Stoneville Research Quarantine Facility (SRQF) received a shipment from China of *Helicoverpa zea* in support of the *Helicoverpa zea* sterile hybrid project; a shipment of miscellaneous pathogens of *Spodoptera* spp. from Indonesia, in support of *Spodoptera* spp. research in South Carolina; two shipments from Cameroon in support of *Callosobruchus maculatus* research in Alabama and Mississippi, one a parasitoid and the other miscellaneous pathogens of *C. maculatus,* in 1993. *Bemisia tabaci* research studies and rearing for those studies continued as the majority of the activity in the SRQF. (W. W. Harrison-Bryan, F. M. Williams)

Production of insects for USDA-ARS research by the Stoneville Insect Rearing Unit required maintenance of eleven insect species: *Heliothis virescens, Helicoverpa zea, Heliothis virescens* sterile hybrid, *Anticarsia gemmatalis, Pseudoplusia includens, Spodoptera exigua, Galleria mellonella, Microplitis croceipes, Cardiochiles nigriceps, Microplitis demolitor,* and *Cotesia kazak*. Support of USDA-ARS scientists at Stoneville and laboratories in Tifton, GA; Mississippi State, MS; Peoria, IL; Ithaca, NY; College Station, TX; and Weslaco, TX; required production of 1,132,500 *H. virescens* pupae; 497,250 *H. virescens* sterile hybrid BC pupae; 338,000 *H. zea* pupae; 234,000 *S. exigua* pupae; 200,000 *A. gemmatalis* pupae; 350,500 *P. includens* pupae; 26,000 *G. mellonella* larvae; 137,500 *M. croceipes* cocoons; 101,700 *C. kazak* cocoons; 45,700 *M. demolitor* cocoons; 31,480 *C. nigriceps* cocoons; 61,368,000

H. virescens eggs; 25,360,000 *S. exigua* eggs; 36,162,000 *H. zea* eggs; 12,840,000 *A. gemmatalis* eggs; and 14,500,000 *H. virescens* sterile BC eggs. Additional research support included sexing 584,000 *H. virescens* and *H. virescens* sterile BC pupae over a seven week period in support of the sterile TBW-BC pilot test; mixing, dispensing, and filling 138,930 30-ml plastic cups and 1,585 3.8 liter multicellular trays with artificial diet. Total diet mixed and dispensed in 1993 was 23,594 liters. Also, assistance was provided to several scientists in rearing insecticide resistant strains of *P. includens* and *H. virescens* and a sterile *H. zea* colony. (G. G. Hartley)

Participation in the Cotton Foundation and American Soybean Association Insect Distribution Programs continues to grow with approximately 150 researchers located in 26 states, Canada, England, Japan, and Germany requesting insects. Participants were supplied with 2,520,500 eggs and 41,082 pupae of the tobacco budworm, bollworm, soybean looper, velvetbean caterpillar, and beet armyworm. Income realized from these programs was used to defray insect rearing expenses. These programs are expected to continue their growth in 1994. (G. G. Hartley)

Velvetleaf, *Abutilon theophrastii* Medikus, and cotton were inspected for eggs and larvae of bollworms, tobacco budworms and beet armyworms, and densities of these pests were tabulated for the peak cotton growing season. Data from these surveys indicated that velvetleaf is a preferred host of tobacco budworms and sustained the offspring of bollworm and tobacco budworm moths that had emerged from local overwintered pupae or had immigrated into the area in the early springtime. Velvetleaf also supported major peaks of eggs of tobacco budworms during the cotton-growing season and substantial tobacco budworm larval populations from late September to November. Velvetleaf that grows in clumps in the rows of growing cotton or at the borders of cotton fields is a major source of pupae that overwinter near cotton fields. In 1992 and 1993, blooms, buds, and fruit of this weed provided attractive feeding sites for budworm, bollworm, and beet armyworm moths. Although cotton supported the majority of beet armyworm larvae during the 1992 and 1993 growing seasons, velvetleaf plants also sustained substantial numbers of beet armyworm larvae in both 1992 and 1993. Greater numbers of bollworm eggs were found on velvetleaf in June of 1992 and 1993 than during the same period in 1991. The parent moths of these

eggs apparently had emerged from fields of matured corn in May and June. During the cotton-growing season, velvetleaf plants were host to about 20 times the number of tobacco budworm eggs found on cotton. Velvetleaf growing in or near cotton fields is considered the single most important weed host that sustains late-season tobacco budworm larval populations that ultimately overwinter as pupae. Smartweed, both white and pink types, that grow in moist ditches near cotton fields also served as a reservoir for larvae that later overwinter as pupae. Destruction of these weeds each fall after cotton harvest is recommended as an annual agronomic practice that could reduce significant numbers of tobacco budworms and bollworms destined to emerge the following spring. (D. E. Hendricks)

An automatic electronic moth detector system incorporated with inverted pheromone traps has been commercialized by Automata, Inc., Grass Valley, Calif. 95945. This system has been used for four years for the detection of tobacco budworm and bollworm moths inhabiting cultivated field crops. The automatic moth detection system was used in Washington Co., Miss. to detect fluctuations in numbers of budworm and bollworm moths throughout the 1993 growing season. Data collected from the automatic system were compared with numbers of moths captured daily in traps installed near cotton fields up to 10 miles away. The automatic moth detection system was used to count moths near cultivated corn and cotton by agricultural consultants near Lubbock, Texas. The automatic moth detectors were baited with appropriate pheromone and interfaced with the data-logger of a portable monitoring station. Moth detection data and weather data were reported upon request by "keying" a cellular telephone installed at the site of the remote weather station. Surveys of bollworm and tobacco budworm moth populations using replicated installations of 30-in. diam. pheromone traps baited with appropriate pheromone baits showed that moth catches from clusters of 3 to 4 traps set 50 ft apart at one location represented true population fluctuations more accurately than did installations of single traps. However, season-long moth trapping data indicated that competition between baits in the traps may bias population profiles when 5 traps or more were used in the clusters. (D. E. Hendricks, J. Willers, B. Hickling)

Population density profiles plotted for the cotton crop season showed a later and significantly smaller build-up of tobacco budworms on cotton in 1993 than in 1992. Wild geranium and crimson clover supported the first 2 generations of tobacco

budworms and bollworms. Velvetleaf, corn, soybeans, and smartweed supported the 2nd to the 5th generations of bollworms. In 1993, dry hot weather conditions were the major causes of low yields of lint cotton. However, beginning in late-July, beet armyworm populations were extremely devastating as they were in 1992. Resistance to insecticides in both tobacco budworms and beet armyworms and the damage they caused reduced overall profits made by cotton producers. Correlation of weather conditions with population profiles during the growing season indicated that a severe winter or springtime freeze or flood would be necessary to delay or prevent early buildup of larval populations during the cotton-growing season and help reduce expense of insecticide application. Natural microbial agents also increase mortality in overwintering insects (pupae) during mild winters. (D. E. Hendricks)

Analysis of genetic material from tobacco budworm moths collected from Texas, Louisiana, Mississippi, Arkansas, and Georgia showed that within local populations, budworm moths typically traveled 8 km or less during a two-week period in the middle of the growing season, and resistance to commonly used insecticides are better dealt with inside the perimeter of local areas of a 8 km diameter. This work supports the inference that single tobacco budworm moths dispersing beyond the limits of this area would not significantly contribute to development of resistance to insecticides in other regions. Initial design of this project was conceived by James Mallet and Amy Korman, Miss. St. Univ., and starch gel electrophoretic analyses were used to determine differences or similarities of moths collected. Preliminary "finger-printing" analyses of *H. zea* moths collected in north central Mexico and 5 southern U. S. states indicate that isoenzymeDNA in moths collected from these different sites were not generally unique and could not readily be used to determine the origin of individual *H. zea* moths. (D. E. Hendricks, K. Narang and many other entomologists in the U.S. and Mexico).

A pheromone (Z)-11-hexadecenal (Z11-HDAL) deployed at the rate of 1 gram/A (0.4 ha), significantly reduced the mating success of female tobacco budworms and decreased captures of male tobacco budworms in traps baited with either females or pheromone (virelure) in 10-A cotton fields. Z11-HDAL caused significant reduction in mating between male and female tobacco budworm moths. Z11-HDAL, dispensed in cellulose acetate filters, was deployed in a 40-A (16 ha) plot of cotton from mid-June to

mid-August. During this period, catches of tobacco budworm and bollworm males in traps baited with pheromone were compared with catches in traps installed in an untreated (CK) plot (40 A) of cotton. The two test plots were nearly adjacent and were on the same farm. Nominal dosage of Z11-HDAL deployed in the treated plot was 0.20 grams/A (0.4 ha)/10-day period during a 60-day period. Catches of both tobacco budworm and bollworm male moths in traps installed in the treated plot were significantly reduced compared with captures in traps installed in the untreated plot. Tobacco budworm and bollworm infestations (larvae and eggs) in the treated plot ranged from 1% (at low moth densities) to 7% (at high moth density levels) when infestation levels in the untreated plot ranged from 3% to 18%, respectively. When the cotton plants were less than 18 in. tall, dispensers were installed at the top of 10-in. or 22-in. (3/16-in.-diam.) dowel rods. In late July and in August, when the cotton plants were 2 1/2 to 4 feet tall, filter dispensers were fastened to a top plant terminal. Within a 2-wk period after the dispensers were installed, more than 94% of the Z11-HDAL dissipated from the filters into the air and plant canopy. (D. E. Hendricks)

Resistance levels to non-pyrethroids in tobacco budworms were evaluated with the adult vial test (AVT). Difficulties were encountered in detecting resistance with the doses used. Data are being evaluated to determine correct doses. (L. H. B. Kanga, F. W. Plapp, Jr., G. W. Elzen)

Evaluation of twelve insect resistant soybean genotypes with different maturity dates was continued to determine if resistance levels change during plant maturation. The studies are conducted in a large field cage utilizing laboratory reared insects. All genotypes have essentially the same level of resistance prior to fruiting. After the onset of fruiting the later maturing genotypes appear to have a higher level of resistance than earlier maturing genotypes. Additional studies will be required to determine if resistance levels decrease during the fruiting phase or if later maturing genotypes develop higher levels of resistance. (L. Lambert)

Evaluations of the USDA-ARS soybean germplasm collection for resistance to insects were continued. In field cage evaluations of 2,400 accessions, several genotypes were identified with high levels of resistance to foliar feeding by soybean looper but none to velvetbean caterpillar. The resistant accessions will be further

evaluated and used in a breeding effort to develop soybean cultivars with high levels of resistance to insects. (L. Lambert, T. C. Kilen)

Studies were continued in small field cages to determine the influence of celery looper virus on second generation soybean looper. As in previous years, the virus completely controlled the second generation of loopers. The study was expanded to determine the influence of BT and a whitener-brightener on effectiveness of the virus (L. Lambert, W. L. Solomon, M. R. Bell)

Studies were continued with soybean isolines of normal, dense and glabrous pubescence types to determine that BT was most effective in controlling soybean looper on glabrous types. (L. Lambert, J. E. Mulrooney)

The second and final release in the pilot test program to control the tobacco budworm by releasing sterile backcross (BC) insects was conducted in 1993. The 1993 program consisted of releasing an average of 70,000 moths per day over a 10 mile square area near Cleveland, Mississippi, beginning 12 April and ending 25 May. The moths were released from pupae placed at 25 release points spaced 2 miles apart. Moth captures in wire cone traps spaced at regular intervals throughout the area showed that a 1.0:1.3 released:wild moth ratio was achieved where a 10.0:1.0 ratio was desired. Continued trap monitoring showed that the sterile:normal ratio dropped to 1.0:1.6, 1.0:3.2, and 1.0:3.8 during June, July, and August, respectively. Field collections of eggs and larvae showed that the species complex was 79 percent *Heliothis virescens* and 21 percent *Helicoverpa zea* in the release area. The species complex in the control area, which was the 1992 release area, consisted of 65 percent *H. virescens* and 35 percent *H. zea*. Trap captures in the control area showed that the overwintered tobacco budworm population was 30 percent BC as a result of the 3.0:1.0 BC:wild release that was made in 1992. The percent BC composition in the control area dropped to 19, 17, and 11 during June, July, and August, respectively. Low temperatures inhibited emergence of moths from pupae placed in the field and an overall emergence of 85.9 percent was obtained. The first wild tobacco budworm moth was captured 26 April, about three weeks later than normally expected. Numbers of eggs and larvae collected in and around the release area were low, and under conditions of the

experiment, no reduction in the July population in the center of the release area as a result of the release was shown. (M. L. Laster, D. D. Hardee, J. C. Schneider)

Mating table studies were conducted for three weeks during May to determine the attractiveness of released and wild males to normal *H. virescens* and BC females. These studies showed that BC females attracted higher numbers of both wild and released males than was attracted by normal *H. virescens* females. This showed that the laboratory-reared and released insects were of good quality from the standpoint of attractiveness. (M. L. Laster)

Research on the tobacco budworm backcross has continued with maintenance of two advanced backcross colonies, currently in the 86th and 216th generations. The 75th generation was increased for the 1993 pilot release. Considering four generations per year for the tobacco budworm in one growing season, the 216th generation represents 54 years of continuous colonization. This colony has been maintained continuously in the laboratory since 1971. Maintenance of these colonies will likely be discontinued upon completion of the pilot test program. (M. L. Laster)

Arrangements for receiving *Helicoverpa armigera* pupae from China into the Stoneville Research Quarantine Facility have been completed. Pupae received will be used in crossing studies with *H. zea* to search for hybrid sterility. (M. L. Laster)

The Insect Rearing Research Unit (IRRU) maintained colonies of *Anthonomus grandis grandis, Heliothis virescens, Helicoverpa zea, Microplitis croceipes,* and *Catolaccus grandis.* Approximately 2 million boll weevils were shipped to Cotton Foundation recipients to support extensive research programs. Various lepidoptera and coleoptera diet formulations were prepared and shipped to Bozeman, Montana, to evaluate assessment of artificial diets for insects feeding on leafy spurge and knapweed plant species. Mass rearing research and production programs were conducted in support of *Heliothis* backcross pupae (700,000/wk for 6-wk period) and *Catolaccus grandis* (12,000/wk and 52,000/wk for 12-wk and 8-wk periods, respectively). *Heliothis virescens* larvae were supplied for large-scale production of *Microplitis croceipes* field tests conducted in Missouri (Steiner) and Alabama (Tillman). Significant mass-rearing research improvements were as follows. 1) Pre- and post-diet filters installed in the flash sterilizer units; 2) Mechanized process for cleaning and disinfecting the diet

dispenser for the thermoforming unit; 3) Adapted *Catolaccus grandis* rearing process for 9,000 females/wk to 52,000 females/wk; and 4) Assessed most advantageous cage size and adult population density for *Catolaccus grandis* maintenance colony. (J. L. Roberson)

Narrow row (30") and normal row spacings (40") of cotton were evaluated for the second year in 1993. Similarities in insect populations, yield, and maturity were evaluated. Two 90-acre fields were used for the study and were separated only by a dirt road. The fields were under different management but had the same soil types. Cotton variety, planting date, fertilization, and herbicide programs were the same. Early season treatments in both plantings included Temik (0.50 lb AI/acre) and Cygon (0.20 lb AI/acre). Both treatments in each field were replicated six times. The 30" cotton received one more application of insecticide for bollworm control than the 40" cotton. A higher infestation of bollworms occurred in the 30" cotton during the last week of July. The 40" cotton received three (4 oz.) applications of PIX and the 30" cotton received five (4 oz.) applications of PIX. The 40" cotton was ready for harvest about a week earlier than cotton planted in 30" row spacings. In 1993, the temik treated cotton yielded more than cotton treated with Cygon for control of early season pests in both row spacings. The 30" cotton had a higher total harvest (100 lbs. lint) than cotton planted in 40" row spacings. (W. P. Scott)

Plant bug populations were sampled in both row spacings throughout the season. There were no differences in populations, probably due to frequent spraying for boll weevil and bollworm control. (W. P. Scott, G. L. Snodgrass)

Under moderate bollworm/budworm pressure in 1993, there were no differences in level of control or yield with Decis, Baythroid, and Karate applied at 0.02, 0.033, and 0.033 lb AI/acre. Decis applied at 0.016 lb AI/acre with and without Larvin (0.25 lb AI/acre) was not as effective as the higher rate. (W. P. Scott)

Spray table and small field plots were used to evaluate new chemistry from Rhone Poulenc on thrips, plant bugs, and boll weevils. Several different molecules of the Fipronil chemistry were very active at low rates against populations of thrips (both in-furrow and foliar), plant bugs, and boll weevils. (W. P. Scott)

The pecan aphid complex is composed of three aphid species: the blackmargined aphid, *Monellia caryella* (Fitch), the yellow pecan aphid, *Monelliopsis pecanis* Bissell, and the black pecan aphid, *Melanocallis caryaefoliae* (Davis). Investigations of host plant resistance, host plant specificity and host plant selection of these three aphid species were conducted at several plant phylogenetic levels. (M. T. Smith)

In the second year of a two-year study, closely related tree species of pecan within the Juglandaceae family of nut trees of North America were evaluated in regard to their suitability as hosts for *M. caryella, M. pecanis* and *M. caryaefoliae*. Nymphal survival and developmental rate and adult survival and reproductive rate were studied on all thirteen hickory (*Carya*) species, one hybrid species (hican) and two walnut (*Juglans*) species. In addition, these studies incorporated the evaluation of host specificity as a function of seasonal changes in host plant phenological stages of development. These studies are being performed on detached leaves of each tree species independent of environmental fluctuations. Data collection is still in progress. (M. T. Smith, B. W. Wood, W. L. Tedders, C. C. Reilly)

In the second year of a two-year study, seven pecan cultivars were evaluated as suitable hosts for *M. caryella*, *M. pecanis* and *M. caryaefoliae*. Pecan cultivars evaluated were selected from across a spectrum of cultivars reported and/or suspected of showing degrees of resistance to pecan aphids, as well as plant pathogens. The seven cultivars included Cape Fear, Chickasaw and Osage (each reported to be resistant to *M. caryaefoliae*), Schley and Sumner (each reported to be susceptible to *M. caryaefoliae*), Pawnee (reported to be resistant to *M. caryella* and *M. pecanis*), and Cheyenne (reported to be susceptible to, or preferred by *M. caryella* and *M. pecanis*). Nymphal survival and developmental rate, and adult survival and reproductive rate were monitored as a function of cultivar and seasonal changes in host plant phenological stages of development. Data collection is still in progress. (M. T. Smith, R. C. Reilly)

In conjunction with the two studies discussed above, investigations of the feeding behavior of *M. caryella, M. pecanis* and *M. caryaefoliae* among the Juglandaceae species and pecan cultivars were performed. These studies were also conducted as a function of host plant phenology. The goal of these studies will be to describe the type of resistance (antibiosis and/or non-

preference) that is reflected in the biological analyses. Data collection is still in progress. (M. T. Smith)

As an extension of the three investigations discussed above, preliminary investigations were conducted on the analysis of pecan aphid biological and behavioral performance on grafted plants of each of the Juglandaceae species and pecan cultivars. Methodology developed from these studies will be utilized in subsequent investigations to confirm results of the investigations discussed above. (M. T. Smith)

In order to discover and understand the mechanisms of resistance associated with the above mentioned studies, both foliar chemical and morphological characteristics are being investigated. Comparative foliar plant chemical analysis of the Juglandaceae species and the pecan cultivars was performed. Both foliar cuticular and internal chemistries were extracted and are currently being analyzed by GC, GC-MS, and HPLC procedures. Although data analysis is still in progress at this time, there are clear differences in the cuticular chemistry among the various tree species and pecan cultivars. (M. T. Smith, R. F. Severson, J. R. Robertson)

Additionally, the surface and internal structure of the Juglandaceae species are being investigated via SEM and light microscopy. Although data collection is still in progress at this time, there are clear differences in the surface morphology and internal anatomy among the various tree species and pecan cultivars. (M. T. Smith, R. Paul)

Investigations were made to determine the utility of trap crops (sequentially attractive) designed to intercept migrating insect pest species as they move from soybean to pecan. Two different trap crop species (cow pea or purple hull pea and hill pea) were evaluated. Population density of several stinkbug species were monitored in the soybeans, trap crop plots, and in pecan trees at increasing distances from the soybeans. Stinkbug damage level was evaluated at several heights within the same trees. Sweep samples have not as yet been thoroughly evaluated, but it appears that the sampling method underestimates stinkbug population levels in the soybeans and in the pecan trees. However, it is apparent that hill pea provided an attractive trap crop for the migrating stinkbugs for a longer period of time than did the purple hull pea. In fact, the hill peas were still producing attractive green

pea pods until the first frost on November 4-5. Therefore, hill pea, would be recommended as a preferred trap crop host plant since it would only require a single planting (less labor), and would provide an attractive trap crop host plant for the stinkbugs until pecan harvest and/or until temperatures would be unfavorable for stinkbug survival. Nut harvest and data collection are still in progress at this time. Therefore, final evaluation of the efficiency of the trap crop to protect pecans from stinkbugs is not yet available. (M. T. Smith, G. L. Snodgrass, T. Jenkins, B. Horton, M. Hughs)

Research was continued on the re-evaluation of the hickory shuckworm sex pheromone. The two additional components discovered in 1992 which were not accounted for previously by any known sex pheromone compound of the hickory shuckworm were identified and evaluated for attractancy as synergists to the known commercial lure. To date, limited evidence suggests some synergism of one of the two new compounds. However, several additional compounds were discovered via EAD analysis. Furthermore, very valuable information was obtained in regard to trap spacing and density within a pecan orchard. [M. T. Smith (MS), G. Greis (Canada), M. Hall (LA), J. McVay (AL), Salvador Galindo (Mexico)]

Research was initiated on the collection, isolation, and chemical characterization of the pheromone of the pecan weevil, *Curculio caryae* (Horn). Orchards have been located for collection of adult weevils, and volatile air collections have been made of male and female weevils of various ages and in combination with host plant tissue (nuts). EAD analysis has shown responsiveness of both male and female weevils to: (1) male weevil + host volatiles; (2) female weevil + host volatiles; (3) host volatiles; (4) male weevil volatiles; and (5) female weevil volatiles. However, EAD analysis of male or female volatiles alone indicated differential responsiveness to two specific GC peaks which were not apparent in the EAD analysis of volatile samples where host odors were present. This may be an indication of several biologically active volatiles unique to the weevils. Therefore, current focus has been placed upon the characterization of these two specific peaks. Additional EAD and chemical analyses are still in progress at the time of this report. Investigations of the cuticular chemistry of the adult pecan weevil were also conducted in cooperation with Dr. Horvat (USDA-ARS, Athens, GA). Chemical characterization of these extracts is currently in progress. Furthermore, very

valuable information has been obtained in regard to the spatial and temporal dynamics of the pecan weevil within an orchard. This information has critical implications with respect to ultimate utilization of a pecan weevil pheromone trap (trap spacing, trap density), as well as to other biological and chemical control strategies for this pest insect. (M. T. Smith, G. Greis, H. Pierce, R. Horvat, J. Mohead, J. Kuhre)

Fungicides applied at planting were evaluated with respect to their potential effects upon the incidence and prevalence of the entomopathogenic fungus *Neozygites fresenii*, a natural controlling agent of *A. gossypii.* Given the significant variation in aphid density within the plant canopy and across the phenological stages of plant development, sampling was conducted at three plant canopy locations. Although thorough analysis of the data from these studies has not as yet been completed, it is clear that at least one fungicide (carboxin) significantly reduces infection of *A. gossypii* by the entomopathogenic fungus *N. fresenii.* Furthermore,analysis of aphid density data has shown that the reduction in fungal infection can in turn result in significantly higher *A. gossypii* population levels. (M. T. Smith, D. D. Hardee)

Factors governing the seasonal dynamics of *A. gossypii* were investigated. Among the biotic factors monitored was the entomopathogenic fungus *N. fresenii*, a natural controlling agent of *A. gossypii*, and the braconid, *Lysiphlebus testaceipes*. Abiotic factors monitored included leaf wetness and air temperature (each recorded at the three locations within the plant canopy), soil moisture, air temperature and relative humidity above the plant canopy, and rainfall. Although data from these studies have not as yet been completely analyzed, it is clear that: (1) *L. testaceipes* and *N. fresenii* are the key natural controlling agents of the cotton aphid during the entire cotton growing season; (2) neither *L. testaceipes* nor *N. fresenii* are solely responsible for population declines of the cotton aphid in early- and late-season, respectively; and (3) aphid density, leaf wetness and source of inoculum represent at least 3 key factors which govern epizootics of *N. fresenii* within the cotton aphid. (M. T. Smith, D. D. Hardee)

Research was initiated on the evaluation of parasitoids of the sweetpotato whitefly (SPWF). Investigations of both biological (age specific fecundity, developmental rate, percent parasitism and percent emergence) and behavioral performance of selected parasitoid species under different environmental (temperature

regimes) and host plant scenarios are in progress. Several strains of a given parasitoid species are also being comparatively evaluated. This research is designed to identify those parasitoid species most appropriate for release and control of the SPWF in very select geographic areas and on high value cash crops in the United States where the SPWF is of major importance (Imperial Valley in California, Rio Grande Valley in Texas, and Florida). Although these studies are still in progress, it is very clear that temperature strongly influences parasitoid efficiency, and therefore, successful control of the SPWF with these natural enemies is vitally dependent upon selection of parasitoid species which are well adapted to the particular environmental conditions in which they are to be utilized for SPWF control. (M. T. Smith, F. M. Williams, D. Lanham, W. Hays, D. D. Hardee, R. Hennessey)

One release of the braconid wasp *Peristenus digoneutis* Loan was made in an alfalfa field infested with its host, the tarnished plant bug, in 1993. The alfalfa field is located in the edge of the Delta near Holcomb, MS, and adult female (120) and male (72) parasites were released on 28 May. The parasites were obtained from Bill Day, Beneficial Insects Research Laboratory, USDA-ARS, Newark, Delaware. The alfalfa field and weedy areas near it were sampled for plant bugs during May-August, and the adults and nymphs collected were dissected for parasites or reared in the laboratory to obtain adult parasites. No adults of *P. digoneutis* were obtained from the laboratory rearing or in the field samples. (G. L. Snodgrass)

The within plant distribution of the tarnished plant bug in cotton was determined for a second year during June-August in a heavily infested field at Stoneville, MS. Results of the study are unanalyzed. (G. L. Snodgrass)

A study of the efficiency of the sweep net for tarnished plant bug adults in cotton was conducted for a second year. Results are unanalyzed, but will be used along with data from the within plant distribution study to develop a predictive equation for the efficiency of the sweep net for adults in cotton. (G. L. Snodgrass)

A field test on the efficacy of Naturalis-L (*Beauveria bassiana*) for control of plant bugs in cotton was conducted during July. Treatments were Naturalis-L, cygon, and an untreated check. Treatments were applied with a high clearance sprayer on 6, 12, 16, and 21 July using 15 oz of Naturalis-L or 0.2 pound of cygon

per acre. Numbers of adults and nymphs found in the plots were determined before the first treatment applications and 3-6 days after each application. The Naturalis-L reduced nymphal populations a mean of 54% compared to the check over the 4-wk period, while the corresponding reduction with cygon was 69%. Adults were reduced 20.2% in the Naturalis-L treatment and 60% in the cygon treatment. (G. L. Snodgrass, G. W. Elzen)

Resistance levels to the insecticides permethrin, bifenthrin, acephate, and endosulfan were determined for adult tarnished plant bugs collected from the weed, *Erigeron annuus*, near cotton fields at Stoneville, MS. For comparison, adults were also collected from *E. annuus* found growing near Crossett, AR (where exposure to the insecticides used in cotton production was minimal). Resistance in both groups was determined using a glass vial bioassay. Results showed no difference in the LC50's for the 2 populations for the insecticides permethrin, bifenthrin, and endosulfan. Resistance to acephate was significantly higher in the Stoneville population. Adult bugs from a population found in cotton near Schlater, MS, in July and August were also tested for resistance to the 4 insecticides using the glass vial bioassay. Resistance to permethrin and bifenthrin in this population was 53 and 35 times, respectively, higher than the Stoneville population. Mortality for adults caged on cotton terminals treated with Pounce (permethrin) at a rate of 0.1 pound per acre was only 7.6% for the Schlater population. These results showed that permethrin used at a rate recommended for control of the bollworm/tobacco budworm in cotton would not control plant bugs also found in the field at Schlater. Resistance in the Schlater population to acephate was not significantly different from the Stoneville population. Resistance in the Schlater population to endosulfan was significantly higher than that found for Stoneville. (G. L. Snodgrass)

Native *Microplitis croceipes* parasitized 15% of the *Heliothis virescens* larvae on geranium in May of 1993. This parasitoid was the predominant species. Additive releases of this parasitoid in this early season plant may significantly reduce the second generation of hosts laying eggs in cotton. (P. G. Tillman)

Host plant collections showed that mainly *Microplitis croceipes* was present early season in geranium, but only *Cardiochiles nigriceps* and *Cotesia marginiventris* were present in cotton fields. This suggests that *M. croceipes* may be more susceptible to early season insecticides, especially methyl parathion which is used for

control of overwintering boll weevils. This also indicates that the best time for augmentative releases or conservation of *M. croceipes* could possibly be early season. (P. G. Tillman)

In the laboratory, *M. croceipes* did not prefer *H. virescens* larvae over *Heliothis* backcross larvae, and no difference in fecundity and development of immatures of *M. croceipes* occurred between these two treatments. Field rates of parasitization by *M. croceipes* were not different for *H. virescens* larvae and *Heliothis* backcross larvae. These two control measures could be used effectively together for control of *H. virescens* in Delta cotton fields. (P. G. Tillman)

A bacterium lethal to *M. croceipes* in low numbers was identified. Rearing efficiency for this parasitoid was increased by using an antibiotic. (P. G. Tillman)

A "release box" has been designed for releasing parasitoids with a reduction in labor, money and space. A method of using cold storage to accumulate large numbers of parasitoids for release at the time when the preferred host larvae are available in the field is being refined. The efficacy of parasitoids released from the release boxes was not significantly different from that of parasitoids which have been reared in cages as in the past. Also, greater number of parasitoids emerge from the release boxes than from the harvested material. Also, this release box is the same one used in releasing backcross larvae, increasing the practicality of using these two techniques together for control of *Heliothis/Helicoverpa*. (P. G. Tillman)

Days 2-6 after adult emergence were determined for *M. croceipes*. This gives the best window in time for releasing this parasitoid in an augmentation program for *Heliothis/Helicoverpa* control. (P. G. Tillman)

Sesame was used as a trap crop for *Helicoverpa zea* and *H. virescens*. These pests preferred ovipositing eggs in sesame. The sesame was also a nursery for the naturally occurring parasitoids. Conservation of *C. nigriceps* and *C. marginiventris* using nursery crops such as sesame can increase and be a viable control method for *Heliothis/Helicoverpa* species. (P. G. Tillman)

A study which examined the interaction of aphicide treatments with smooth and hairy isolines of DES 119 cotton provides data useful in assessing the yield impact of cotton aphids. Both isolines were

monitored for cotton aphid, *Aphis gossypii* Glover, densities and effects on yield in aphicide-treated and untreated plots. Treated plots received two dicrotophos applications (0.2 and 0.4 lbs/A), one week apart, when the number of aphids approached 30 per leaf. All plots were treated with oxamyl for tarnished plant bug and boll weevil, and with thiodicarb for budworms and bollworms, at recommended rates needed to maintain these pests at equal low densities. The latter two compounds minimally impacted cotton aphid populations. Numbers of cotton aphids differed significantly between aphicide-treated and untreated plots, regardless of isogenic line, for about 2 weeks during mid-July, the period of rapid aphid population increase. Numbers of aphids in aphicide-treated plots were maintained below 50 per leaf and did not differ between the smooth and hairy isolines. In the untreated plots, numbers of aphids on the smooth isoline approached 100 per leaf while those on the hairy isoline were significantly higher, exceeding 200 per leaf. Yields for the hairy isoline with aphicide, the smooth isoline without aphicide, the smooth isoline with aphicide, and the hairy isoline without aphicide were 2594, 2379, 2331, and 2267 lbs seed cotton/A, respectively. These data indicated that cotton aphid caused a significant yield loss (327 lbs seed cotton/A) in the normal, hairy isoline of DES 119 when it was not protected by aphicide. No yield differences were observed between aphicide-treated and untreated plots containing the smooth isoline; however neither of these treatments yielded numerically as well as the hairy isoline with aphicide. No differences were observed in the densities of, nor damage caused by, major cotton pests which could account for the observed yield loss. Apparently, the damage occurred during the critical period of aphid population increase in mid-July. A search for aphid-resistant cotton lines with high yield potential is suggested. It is plausible that there are high yielding, smooth lines which need no chemical protection from aphids to assume maximum yield potential. (A. A. Weathersbee III, D. D. Hardee, W. R. Meredith)

A study was conducted to examine the interaction of aphicide treatments with fungal entomopathogen, *N. fresenii*, activity. The experiment was designed to assess the impact of cotton aphid on cotton yield and to determine the extent to which the pathogen prevents yield loss due to cotton aphid. Aphid density and entomopathogen infection rates were monitored in plots treated with aphicide, fungicide, both or neither. Assessment of yield savings offered by *N. fresenii* was not possible because the fungicide used was not effective in manipulating entomopathogen

activity in the field. Laboratory tests indicated the fungicide possessed activity against *N. fresenii* but it did not prevent the occurrence of an epizootic in field populations of cotton aphid. Additional fungicide screening will be necessary before this portion of the test can be completed. Nevertheless, data from the aphicide portion of the test provided results similar to those reported in the preceding narrative. DES 119 (normal, hairy line) yielded 2570 lbs seed cotton/A in response to two applications of dicrotophos but only 2016 lbs when untreated. The significant yield loss of 554 lbs seed cotton/A was attributed to cotton aphid damage. No significant differences were observed for other pest densities or damages which were maintained at similar low levels among treatments. (A. A. Weathersbee III, D. D. Hardee)

Data were collected during the period two weeks before and through the epizootic in cotton aphids caused by the fungal entomopathogen, *N. fresenii.* These data will be used to identify parameters useful in developing a regression equation to predict the occurrence of the epizootic. Initial results indicate that the number of live alate cotton aphids may be a good predictor of the onset of the disease while the numbers of dead alate and apterous aphids may be good predictors of the time of greatest entomopathogen activity. Comprehensive results are pending analysis of data. Observations from two years of study involving this entomopathogen indicate that the onset of disease coincides with a sudden increase in the density of cotton aphids about the second week of July. The full potential of *N. fresenii* is realized within seven to ten days of initial appearance. The epizootic appears to recur annually about the same time (3rd week in July) regardless of planting date or weather conditions. (A. A. Weathersbee III, D. D. Hardee)

A study was conducted during an epizootic in cotton aphids caused by the entomopathogen, *N. fresenii*, to determine the fate of primary conidia (spores) released from aphids which die from fungal infection. The previous consensus was that conidia were released only to the area of the leaf immediately surrounding the dead aphid and that the disease was transmitted through aphid movement and contact with conidia on the leaf. Wind aided dispersal of this pathogen has not been previously documented. Our data prove that aerial dispersal of primary conidia occurs with great frequency and is likely the most important mode of disease transmission within a cotton field. Primary conidia germinate to form secondary conidia (infective spores) upon landing on a

suitable substrate. Conidia were collected overnight on both upper and lower surfaces of collection devices (35 x 10 mm petri dishes containing water agar) used to simulate cotton leaves, placed at 0.5 m (middle canopy) and 1.5 m (above canopy) above the ground, both inside and 3 m outside of a cotton field. Spores were collected at all positions but tended to occur with greater frequency on upper than lower surfaces, and appeared more prevalent within the canopy than above and within rows of cotton than outside. These data help explain the rapidity with which this disease overtakes the entire aphid population within a cotton field only shortly after it is observed present in the field. (A. A. Weathersbee III, D. D. Hardee)

2. Extramural

Studies were continued by P. P. Sikorowski through a Cooperative Agreement (ARS-MAFES) on the presence of a nonoccluded baculovirus within the egg of *Microplitis croceipes*. The project is completed, and this method is available to screen *Microplitis croceipes* colonies for presence of nonoccluded baculovirus in adult parasites. (P. P. Sikorowski, J. L. Roberson)

B. Indicators of Progress

1. Publications (Published, In Press, Accepted)

Bell, M. R., and J. L. Hayes. 1993. Area-wide management of cotton bollworm/tobacco budworm through application of a nuclear polyhedrosis virus on early-season alternate hosts. J. Econ. Entomol. (Accepted 4 April 1993).

Bell, M. R., and D. D. Hardee. 1993. Development of an area-wide program for management of *Heliothis/Helicoverpa* through early-season application of an entomopathogenic virus - 1992 field trial, pp. 865-868. In Proc. Beltwide Cotton Prod. Res. Conf.

Elzen, G. W. 1993. Tobacco budworm insecticide resistance in the Mississippi Delta, pp. 25-27. In Proc. Beltwide Cotton Prod. Res. Conf.

Elzen, G. W. 1993. Evaluation of biologicals for control of lepidopterous pests, 1992. Insecticide & Acaricide Tests. 18: 366-367.

Elzen, G. W. 1993. Cotton aphid control, 1991. Insecticide & Acaricide Tests. 18: 221.

Elzen, G. W. 1993. Cotton aphid control, 1992. Insecticide & Acaricide Tests. 18: 222.

Elzen, G. W. 1993. Evaluation of insecticides for control of tarnished plant bugs, 1992. Insecticide & Acaricide Tests. 18: 366.

Elzen, G. W. 1993. Evaluation of *Heliothis* insecticide resistance levels, 1992. Proc. 39th Miss. Insect Control. Conf., (Abstract), pp. 22-23.

Elzen, G. W., S. H. Martin, and J. B. Graves. 1993. Characterization of tobacco budworm resistance: Seasonal aspects and synergism, pp. 1024-1028. In Proc. Beltwide Cotton Prod. Res. Conf.

Elzen, G. W., S. H. Martin, B. R. Leonard, and J. B. Graves. Inheritance, stability, and reversion of insecticide resistance in tobacco budworm (Lepidoptera: Noctuidae) field populations. J. Econ. Entomol. (In Press)

Elzen, G. W. Characterization of *Heliothis virescens* (F.) resistance in Mississippi in 1992. Southwest. Entomol. (Accepted November 1993).

Gueldner, R. C., I. E. Yates, C. C. Reilly, B. W. Wood, and M. T. Smith. 1993. Levels of a hydrojuglone glucoside in developing pecan leaves in relation to scab resistance. J. Horticultural Science. (Accepted July 1993).

Hardee, D. D. 1993. Resistance in aphids and whiteflies - principles and keys to resistance management, pp. 20-23. In Proc. Beltwide Cotton Prod. Res. Conf.

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3. <u>Presentations</u>

Bell, M. R. "Development of an area-wide program for management of *Heliothis* spp. through early season application of an entomopathogenic virus - 1992 field trial." Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993.

Bell, M. R. "Management of bollworm and tobacco budworm by large area applications of entomopathogenic viruses." Southeastern Branch, ESA, Little Rock, AR, March 1993.

Elzen, G. W. "Tobacco budworm insecticide resistance in the Mississippi Delta." Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993. (Invitation)

Elzen, G. W., S. H. Martin, and J. B. Graves. "Characterization of tobacco budworm resistance: Seasonal aspects and synergism." Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993.

Elzen, G. W. "*Heliothis* resistance program." 20th Annual Delta Ag Expo, Cleveland, MS, January 1993. (Invitation)

Elzen, G. W. "Budworm resistance in 1992." Rhone-Poulenc Mid-South Cotton Seminar, Monroe, LA, January 1993. (Invitation)

Elzen, G. W. "Temporal patterns of multiple resistance in tobacco budworm populations." Southeastern Branch ESA Meeting, Little Rock, AR, March 1993.

Elzen, G. W. "*Heliothis* resistance." Cotton Insect Management Program, Miss. Coop. Ext. Ser., Indianola, MS, March 1993. (Invitation)

Elzen, G. W. "Tobacco budworm resistance." Cotton Insect Management Program, Miss. Coop. Ext. Ser., Belzoni, MS, March 1993. (Invitation)

Elzen, G. W. "Survey of selected tobacco budworm populations for changes in insecticide resistance levels." IRAC Cotton-US Committee, Monroe, LA, September 1993. (Invitation)

Elzen, G. W. "*Heliothis* resistance levels and synergism tests." Ciba Extension Entomologist Meeting, Destin, FL, October 1993. (Invitation)

Elzen, G. W. "Chemical methodologies and bioassays for natural products." ARS Working Conference on Natural Products for Control of Agricultural Pests, Athens, GA, October 1993. (Invitation)

Elzen, G. W. "Status of insecticide resistance in TBW." Tri-State Tobacco Budworm IRM Meeting, Northeast Research Station, St. Joseph, LA, November 1993. (Invitation)

Elzen, G. W. "Evaluation of tobacco budworm resistance in 1993." Miss. Insect Control Conf., November 1993.

Elzen, G. W., S. H. Martin, J. B. Graves, and B. R. Leonard. "Inheritance, stability, and reversion of insecticide resistance in tobacco budworm field populations." ESA National Conference, Indianapolis, IN, December 1993.

Hardee, D. D. "Resistance in aphids and whiteflies: Principles and keys to management." Special Session: Insecticide Resistance Management, Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993. (Invitation).

Hardee, D. D. "Sampling of the cotton aphid". Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993.

Hardee, D. D. "Research and Action Plan Progress: Crop Management Systems and Host Plant Resistance (Section E)," (with G. G. Still). Sweetpotato Whitefly Workshop for Development of National Research and Action Plan, Tempe, AZ, January 1993. (Invitation).

Hardee, D. D. "Update on entomology programs with ARS at Stoneville: Sterile moth release, Elcar project, and aphids." 12th Annual Meeting, Mississippi Agricultural Consultants Association, Greenwood, MS, February 1993. (Invitation).

Hardee, D. D. "Boll weevil, *Anthonomus grandis* Boheman: A summary of research on behavior as affected by chemical communication." Centennial Symposium on the Cotton Boll Weevil, San Antonio, TX, April 1993. (Invitation).

Hardee, D. D. "Summary of ARS research at Stoneville." Delta Council User's Advisory Committee, Stoneville, MS, September 1993. (Invitation).

Hardee, D. D. "Area-wide management of tobacco budworm." USDA Committee on Area-Wide Management of Pests, Beltsville, MD, September 1993. (Invitation).

Hardee, D. D. "Proposed area-wide research for tobacco budworm in 1994." Tobacco Budworm Area-Wide Management Meeting, Stoneville, MS, November 1993. (Invitation).

Hardee, D. D. "Summary of cotton insect research at Stoneville." Delta Council Cotton Research Review, Stoneville, MS, November 1993. (Invitation).

Hardee, D. D. "Report of Mississippi Entomological Association Long-Range Planning Committee." 40th Annual Mississippi Insect Control Conference, Mississippi State, MS, November 1993. (Invitation).

Harrison, W. W., and D. A. Herbert. "Burrowing behavior of *Microplitis croceipes* (Cresson) (Hymenoptera: Braconidae) parasitized *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) larvae and disruption of parasitoid cocoon location by soil tillage practices." Eastern Branch ESA, Williamsburg, VA, February 1993.

Harrison-Bryan, W. W., and D. A. Herbert. "*Microplitis croceipes* (Hymenoptera: Braconidae) for control of *Helicoverpa zea* (Lepidoptera: Noctuidae) in soybean and cotton: Investigations for enhanced rearing practices, and opportunities for conservation and augmentation." Patricia Roberts Harris Fellowship Poster Session, Washington, D.C., December 1993.

Harrison, W. W., and D. A. Herbert. "Effect of parasitoid age on oviposition and emergence of *Microplitis croceipes* (Hymenoptera: Braconidae) an endoparasitoid of *Helicoverpa zea* (Lepidoptera: Noctuidae)." ESA National Conference, Indianapolis, IN, December 1993.

Harrison, W. W., and D. A. Herbert, Jr. "Conservation of *Microplitis croceipes* through tillage practices and early season host associations in eastern Virginia." ESA National Conference, Indianapolis, IN, December 1993.

Hendricks, D. E. 1993. "Implementation and accuracy of an electronic system used in conjunction with pheromones to automatically detect and count tobacco budworm and bollworm moths." Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993.

Hendricks, D. E. 1993. "Accuracy of an electronic system used with pheromone traps to automatically detect and count tobacco budworm and bollworm moths." Southeastern Branch, ESA, Little Rock, AR, March 1993.

Scott, W. P. "Insect pest populations in 30" vs. 40" cotton." Rhone Poulenc Cotton Seminar, Monroe, LA, January 1993. (Invitation).

Scott, W. P. "Results of 1992 Decis trial." Rhone Poulenc Cotton Seminar, Monroe, LA, January 1993. (Invitation).

Scott, W. P. "Achieving earliness in cotton in Alabama." Cotton Production Workshop, Auburn, AL, December 1992.

Smith, M. T., and D. D. Hardee. "Influence of fungicides applied at planting on seasonal development of the entomopathogenic fungus *Neozygites fresenii* (Nowakowski) Batko in the cotton aphid, *Aphis gossypii* Glover." Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993.

Smith, M. T., and D. D. Hardee. "Seasonal relationship among cotton aphid (*Aphis gossypii* Glover), the entomopathogenic fungus *Neozygites frensenii* (Nowakowski) Batko, and the parasite *Lysiphlebus testaceipes* (Cresson)." Beltwide Cotton Prod. Res. Conf., New Orleans, LA, January 1993.

Smith, M. T., B. W. Wood, C. C. Reilly, W. L. Tedders, R. C. Gueldner, and R. F. Severson. "Pecan aphid pest management: Searching for sources of aphid resistance in plants." 86th Southeastern Pecan Growers Association Convention, Biloxi, MS, March 1993.

Smith, M. T., and D. D. Hardee. "Seasonal relationship among cotton aphid (*Aphis gossypii* Glover), the entomopathogenic fungus *Neozygites frensenii* (Nowakowski) Batko, and the parasite *Lysiphlebus testaceipes* (Cresson)." Southeastern Branch, ESA, Little Rock, AR, March 1993.

Smith, M. T. "An overview of pecan insect research at the USDA-ARS Stoneville Laboratory: Emphasis on alternatives to pesticides." Mississippi/Louisiana Pecan Growers Conference, Vicksburg, MS, June 1993.

Smith, M. T. "Pecan pest management: Pecan aphid-host plant interactions." Seminar presented to the Department of Entomology, Mississippi State University, Mississippi State, MS, October 1993.

Smith, M. T., and D. D. Hardee. "Influence of fungicides applied at planting on seasonal development of the entomopathogenic fungus *Neozygites fresenii* (Nowakowski) Batko in the cotton aphid, *Aphis gossypii* Glover." Proc. 39th Miss. Insect Control Conf., Mississippi State, MS, November 1993.

Smith, M. T., C. C. Reilly, B. W. Wood, and W. L. Tedders. Insect:Plant interactions among three pecan aphid species. Entomological Society of America National Meeting, Indianapolis, Indiana, December 1993.

Snodgrass, G. L. "Distribution of the tarnished plant bug within cotton plants." Southeastern Branch Meeting, ESA, March 1993, Little Rock, AR.

Snodgrass, G. L. "Distribution of the tarnished plant bug within cotton plants." Beltwide Cotton Prod. Res. Conf., January 1993, New Orleans, LA.

Snodgrass, G. L "Pyrethroid resistance in a field population of the tarnished plant bug in cotton in the Mississippi Delta." 40th Annual Miss. Insect Control Conf., Mississippi State, MS, November 1993.

Tillman, P. G. "Action-area report on biological control." National *Heliothis/Helicoverpa* Workshop, Junction, TX, November 1993.

Tillman, P. G. "Disposable cardboard box for rearing/release of parasitoids of *Heliothis/Helicoverpa*." 40th Annual Miss. Insect Control Conf., Mississippi State, MS, November 1993.

Tillman, P. G. "Biological control of *Heliothis/Helicoverpa* in the United States." Third International Conference on Pests in Agriculture, Montpellier, France, December 1993.

Weathersbee, A. A., III, and D. D. Hardee. "Indices of relative abundance for the cotton aphid, *Aphis gossypii* Glover, and associated parasitoids, pathogens, and predators on six cotton cultivars." Proc. Beltwide Cotton Prod. Conf., New Orleans, LA, January 1993.

Weathersbee, A. A., III, and D. D. Hardee. "Effect of cotton aphid on cotton yield: Interaction of plant genotype and aphid population." 40th Annual Miss. Insect Control Conf., Mississippi State, MS, November 1993. (Invitation).

4. <u>Other Reports</u>

None.

IV. PLANNED RESEARCH CALENDAR YEAR 1994

A. Narrative

1. In-House

Possible plans for 1994 include a large area test incorporating the application of an entomopathogenic virus on weeds within a large area of crop land in the Mississippi Delta. A 20 mile diameter test has been proposed. The test would require the application of virus on an area of at least 314 square miles (201,037 acres) located in the Mississippi Delta near Stoneville. The test area selected has been used for testing and has been monitored for insect populations by researchers at SIML for the past 8 seasons; therefore considerable background knowledge is available. Although pheromone traps would again be used, the major evaluation of effectiveness would be based on actual numbers of budworm or bollworm larvae or eggs found in cotton fields within the area during the first seasonal infestation by these pests. The numbers would be compared to those found in the untreated area surrounding the treated area, and fields well away from the treated area. Other additive control measures within the test area, and those measures that may be taken against the first generation of larvae on cotton to further reduce the populations of these pests, may also be considered and tested. (M. R. Bell, G. L. Snodgrass, D. D. Hardee, A. A. Weathersbee)

In order to conduct a large test, we must produce the virus. We have some of the knowledge and abilities to produce the virus required for the study, but additional work will be necessary to process and formulate the virus into a usable material. (M. R. Bell)

Studies on a new baculovirus having a broad host range (celery looper virus) will continue through laboratory bioassays against tobacco budworms, cotton bollworms, and other available insect hosts, as well as continued studies of the new virus having increased effectiveness against beet armyworms. (M. R. Bell)

Additional cage and infection studies will be conducted whereby the early season weed hosts of lepidopterous pests in the Mississippi Delta are treated with various entomopathogens for evaluation of effectiveness in area wide pest management programs. The objective of these studies will be to determine the effectiveness of various pathogens in reducing the emergence of tobacco

budworms, cotton bollworms, and other pest species from early season hosts. (M. R. Bell)

Studies will continue in the laboratory to examine the most efficient methods and hosts for the mass production of pathogens. Various hosts being reared in the laboratory will be examined to determine the greatest yield at the lowest cost. (M. R. Bell)

Monitoring of resistance levels to all classes of insecticides in tobacco budworms with the AVT and spray table bioassays (include B t's) and refining of correct doses will be continued. Mixtures for efficacy on resistant populations will be evaluated. Complete testing for synergizable resistance in tobacco budworms collected in 1993 will be done. (G. W. Elzen, S. H. Martin, J. B. Graves, F. W. Plapp, Jr.)

The effects of mixtures, synergists, and discriminating doses of insecticides on eggs and adults of resistant tobacco budworms will be determined. (G. W. Elzen)

Evaluation of mixtures and synergists on field collected beet armyworms will be continued. Resistance levels will be determined early and further evaluated during the season. (G. W. Elzen)

We will determine if any cross-resistance in tobacco budworms caused by metabolism exists between endosulfan and pyrethroids, as well as the effect of fenoxycarb as a synergist. (G. W. Elzen)

The additivity or synergism of low and high dose mixtures of Bt with a pyrethroid and carbamate will be studied. (G. W. Elzen)

Studies will continue on influence of planting date and insecticide treatments on in-season development of insecticide resistance in cotton aphids and yield of cotton. Surviving aphids from all treatments will be subjected to laboratory treatments with commonly used aphicides. All cotton insects besides aphids will be controlled when threshold counts warrant their treatment. (D. D. Hardee)

In conjunction with the area-wide management program with Elcar (see M. R. Bell), other contributing factors in suppression of bollworms/budworms will be evaluated as well. These include augmentative releases of parasites and nematodes, plantings of transgenic cotton and a nectariless, smoothleaf variety, early

season applications of biological insecticides, use of pheromones as attracticides, and release of sterile hybrid moths. (D. D. Hardee)

The Stoneville Research Quarantine Facility (SRQF) will continue to receive in-coming shipments in support of research as a regional and national quarantine facility in the biological control of the sweetpotato whitefly, *Bemisia tabaci* and *Helicoverpa zea* sterile hybrid research. (W. W. Harrison-Bryan)

Greenhouse testing on burrowing activities of *M. croceipes* parasitized and non-parasitized *H. zea* larvae in three soil types will be continued. (W. W. Harrison-Bryan)

Examinations of conservation methods of biological control for *M. croceipes* as a control agent for *H. zea* in soybean and cotton will continue. (W. W. Harrison-Bryan)

The Stoneville Insect Rearing Research support group will maintain eleven insect species in 1994. These are tobacco budworm, tobacco budworm sterile hybrid BC, bollworm, soybean looper, beet armyworm, velvetbean caterpillar, greater wax moth, *Cardiochiles nigriceps, Microplitis demolitor, Microplitis croceipes,* and *Cotesia kazak*. Also, assistance will be given individual scientists in maintaining insecticide resistant strains of several species. Artificial diet will be supplied in 30 ml plastic cups and 3.8 liter multicellular trays. Efforts will be made to develop a economical disposable multicellular larval rearing container that is compatible with Stoneville multicellular insect rearing techniques. Also, efforts will continue to produce high quality insects and diets at economical prices. Our work with industry in providing training in insect rearing techniques and transfer of insect rearing technology will continue. The work of approximately 150 scientists within USDA-ARS, private industry, and state universities will be supported by the work of this group. (G. G. Hartley)

The insect distribution programs with the Cotton Foundation and the American Soybean Association will continue in 1994. A healthy participation is anticipated for both programs. Funds provided by these programs will be used to defray insect rearing expenses of the Southern Insect Management Laboratory. Prices for insects may be increased in 1994 to keep pace with rising labor costs, but this will be determined after both programs are evaluated. The egg and pupal stage of the following species will be available: tobacco

budworm, bollworm, soybean looper, velvetbean caterpillar, and beet armyworm. (G. G. Hartley)

We will formulate and field test bioactive materials including attractants, disruptants, or attracticides affecting mortality or the behavior of insect pests of cotton and other agronomic or wild host plants in efforts to suppress destructive populations of tobacco budworm and bollworm. (D. E. Hendricks)

The sequence of occurrence and the distribution of *Heliothis/Helicoverpa* spp. and beet armyworm (if present) on host plants, including wild geranium, crimson clover, cotton, corn, soybean, and smartweed and correlate population fluctuations with annual climatic conditions will be studied. (D. E. Hendricks)

We will develop techniques to optimize methods for detecting insect populations of tobacco budworm and bollworm in field conditions, and monitoring their densities and dispersal habits. (In Cooperation with agricultural consultants, insect population prediction modelers, specialized equipment designers, and the Physical Acoustic Lab, Oxford, Miss.). (D. E. Hendricks)

The population density fluctuation patterns will be determined of bollworm and tobacco budworm eggs, larvae, and moths and we will develop correlations with environmental factors prevailing in typical agronomic conditions in the local Mississippi River Delta region (bollworm and tobacco budworms). (D. E. Hendricks)

Studies to use sound and video observations to determine the behavior of foliar feeding insects which damage soybean will be initiated. (L. Lambert)

Studies will be continued to determine if the genetic removal of soybean plant pubescence enhances the resistance levels of soybean genotypes with foliar feeding resistance to all species of foliar feeding insects. (L. Lambert, T. C. Kilen)

Studies will be continued to determine if plant pubescence influences the effectiveness of BT and other pesticides. (L. Lambert, J. E. Mulrooney)

Studies will be continued to determine the influence of soybean plant maturity on insect resistance. (L. Lambert)

Studies will be continued to determine if a practical method can be developed for using an insect virus to control soybean damaging insects. (L. Lambert, M. R. Bell)

Evaluations of the USDA-ARS soybean germplasm collection will continue in an effort to identify resistance to velvetbean caterpillar species of soybean damaging insects. (L. Lambert, T. C. Kilen)

The IRRU will maintain colonies of *Anthonomus grandis grandis, Heliothis virescens, Helicoverpa zea, Microplitis croceipes,* and *Catolaccus grandis* for mass rearing research and production service. Diet preparation, tray assembly materials, and colony insects will be provided upon request to local federal and state scientists and off-site Cotton Foundation recipients for reimbursement of material and processing costs. An active technology transfer policy will be continued with other insect rearing operations (federal, state, and commercial) to incorporate mechanized production processes within their programs. (J. L. Roberson)

Major mass rearing programs of the IRRU will be as follows: 1) critique of *Catolaccus grandis* oviposition for adaptation to expanded production programs; 2) develop artificial diets for lepidopterous and coleopterous insects feeding on knapweed and leafy spurge range plants; 3) mechanized package system to produce and ship *Microplitis croceipes* parasites; and 4) investigations to reduce cost of *Heliothis* diet. (J. L. Roberson)

A major *Heliothis zea* mass rearing program (8 million) is planned to provide larvae for production of baculovirus. Research plans are not finalized to estimate boll weevil production to support *Catolaccus grandis* research. (J. L. Roberson)

Further studies will continue comparing insect populations and yield and earliness on narrow row vs. normal row spacings of cotton. The effectiveness of temik and cygon as treatments to control early season pests will continue to be a part of the study. Plans are to work with a producer that is willing to plant both row spacings in replicated plots in the same field. (W. P. Scott)

Studies are planned to measure the effect of more recent varieties of a nectariless cotton in reducing plant bug populations. (W. P. Scott, G. L. Snodgrass)

Large field plots will be used to evaluate deltamethrin (Decis) in comparisons with other pyrethroids on cotton insect pest populations. (W. P. Scott)

Small plot tests will be used to carry out more detailed studies on Rhone Poulenc's Fipronil chemistry against cotton pests. (W. P. Scott)

Investigations to elucidate the mechanism(s) which govern the host specificity of *M. caryella, M. pecanis* and *M. caryaefoliae* among the hickory and walnut species native to the United States, as well as among the pecan cultivars, will be expanded to include the utilization of grafted plants of each Juglandaceae species and pecan cultivars. Comparative analysis of the foliar cuticular chemistry of pecan, the other hickory and walnut species, as well as the various pecan cultivars will continue and be expanded to include the intracellular and phloem tissues. (M. T. Smith, R. F. Severson, C. C. Reilly, B. W. Wood)

Investigations of the potential role of leaf surface and/or internal morphology in host plant resistance among the Juglandaceae and the various pecan cultivar will continue. (M. T. Smith, R. Paul)

Behavioral bioassays will be developed in order to determine the role of specific foliar chemistries in the host selection behavior of the three pecan aphid species, particularly in relation to the identification of natural products for aphid control (toxins and/or antifeedents). The behavioral bioassays, artificial diet procedures and electronic feeding monitor analyses, will be initiated to determine the role of specific foliar internal chemistries (i.e. phloem and/or intracellular) in the host acceptance behavior, and which govern the host suitability for aphid growth and reproduction. (M. T. Smith, R. F. Severson)

Investigations will be refined to determine the utility of trap crops (sequentially attractive) designed to intercept migrating insect pest species (stink bug species) as they move from soybean to pecan. Based upon the 1993 test results, hill pea or another pea species which flowers season-long will be evaluated. The sampling method for stinkbugs will be modified. (M. T. Smith, G. L. Snodgrass, B. Horton, T. Jenkins, M. Hughs, T. Winters)

Research designed to re-evaluate the hickory shuckworm (HSW) sex pheromone will be continued. Additional chemical analysis and field bioassays are planned, particularly to include both insect and/or host odors. (M. T. Smith, G. Greis, M. Hall, J. McVay, plus cooperators in Mexico)

Research of the pecan weevil (PW) pheromone will continue. Additional volatile collections, and EAD and chemical characterization will be performed, as well as field evaluation of various chemistries (insect and/or host odors) for attractancy to the weevil. (M. T. Smith, G. Greis, H. Pierce, R. Horvat, J. Mohead, J. Kuhre)

Research will also be conducted to determine the role of host odors in the mating behavior of the HSW and the PW. In addition, the 'Mating Disruption' technique will also be evaluated for the HSW. (M. T. Smith, R. Horvat, plus cooperators in Mexico)

Research will also be conducted in cooperation with Biosys to evaluate several entomopathogenic nematodes for control of the pecan weevil. (M. T. Smith, R. W. Martin (Biosys), J. Mohead).

Investigations of the factors (biotic and abiotic) governing the seasonal dynamics of *A. gossypii* will be continued. Among the biotic factors monitored will be the entomopathogenic fungus *N. fresenii*, a natural controlling agent of *A. gossypii*, and *L. testaceipes*. Abiotic factors monitored will include leaf wetness and air temperature, each recorded at the three locations within the plant canopy. In addition, soil moisture, air temperature and relative humidity above the plant canopy, as well as rainfall will also be monitored. The ultimate goal of this research is to identify key factors which might be manipulated which would result in an earlier onset of *N. fresenii* epizootics within *A. gossypii*. (M. T. Smith, D. D. Hardee, T. Wagner)

Investigations of the progression of the disease process within the cotton aphid will be conducted. The objective of this research is to investigate disease characteristics which might be used to predict a subsequent fungal epizootic within a localized cotton aphid population. The ultimate goal of this investigation is to provide a simple and reliable method to determine visually the presence of the disease within a field, and to predict the development of an epizootic within the cotton aphid population. (M. T. Smith, D. D. Hardee, A. A. Weathersbee, III)

Insect:plant:parasitoid interactions of the Sweetpotato whitefly, *Bemesia tabaci* Gennadius, will be continued. More specifically, host finding and host selection processes of various parasitoid species of *B. tabaci* will be investigated in a comparative study of a wide range of its known host plant species. Natural enemy developmental biology, feeding behavior, and oviposition and searching behavior will be investigated. (M. T. Smith, R. Hennessey, F. M. Williams)

An alfalfa field located in the edge of the Mississippi Delta near Holcomb will be intensively sampled to determine if a braconid parasite, *Peristenus digoneutis*, of tarnished plant bug nymphs became established in the field after its release there in 1992 and 1993. Weedy areas within 2-3 miles of the field will also be sampled for the parasite. Parasitism rates will be determined by dissection of nymphs. Nymphs will also be reared in the laboratory to obtain adult parasites. Additional adult parasites will be released if they are available. (G. L. Snodgrass)

Experiments on sampling tarnished plant bugs in cotton will be conducted in 1994. These include studies on how capture efficiency of the sweep net changes for adults on different plant parts, and how it changes as the plants increase in size. A replicated field test comparing efficiency of the sweepnet to an absolute sampling method for plant bugs will also be conducted. (G. L. Snodgrass)

A large area pilot test for control of the bollworm/tobacco budworm will be evaluated for its effectiveness. The F_1 larvae of these two pests will be controlled by aerial application of a virus to their wild early-season host plants. The evaluation will determine the effect of this control on subsequent populations of the two pests that develop in cotton in the treated area. Evaluation will be made using egg and larval counts taken in cotton within the treated area and in two other untreated areas of similar size. (G. L. Snodgrass, M. R. Bell, D. D. Hardee)

Resistance to pyrethroids in a plant bug colony established using adults collected from cotton near Schlater, MS will be investigated. Experiments include inbreeding the colony and periodically determining resistance levels to see how resistance changes; synergist studies to determine if resistance is due to esterases, microsomal oxidases, or glutathione-s-transferase; determination of whether or not the resistance is sex linked; fitness determination

(egg production, egg viability, nymphal survival, etc.); and the use of selection with permethrin to increase resistance. (G. L. Snodgrass)

We will evaluate the effect of crimson clover as a cover crop on parasitization of *H. zea* and *H. virescens* by native parasitoids in cotton. (P. G. Tillman)

The effect of a nursery with a seasonal succession of host plants on parasitization of *H. zea/H. virescens* in cotton will be studied. (P. G. Tillman)

We will continue to improve parasitoid rearing techniques. (P. G. Tillman)

Parasitoid releases in early-season versus mid-season will be evaluated. (P. G. Tillman)

We will compare susceptibility to currently used insecticides between *M. croceipes* and *C. nigriceps*. (P. G. Tillman)

Studies on breaking of diapause for *M. croceipes* will be initiated. (P. G. Tillman)

We will evaluate the effect of an overwintering refuge for *M. croceipes* on population dynamics of this insect and subsequent suppression of *Heliothis/Helicoverpa*. (P. G. Tillman)

Cooperative research with W. R. Meredith will continue with emphasis on understanding the differences in cotton aphid impact on yield among isogenic lines of specific cultivars. This year's study with smooth and hairy isolines of DES 119 will be repeated with the addition of at least two more isolines, either of the same or possibly a different cultivar. Differences in aphid density will be established while other pests will be maintained equally among treatments. Density and damage estimates will be monitored weekly. Cotton yield and maturity will be assessed at the end of the season. (A. A. Weathersbee, III, D. D. Hardee, W. R. Meredith)

An evaluation of the impact of *N. fresenii* on reducing the yield loss due to cotton aphid will be repeated in field plots. The ability to conduct the experiment will depend on the location of an effective fungicide which can be used to manipulate activity of the pathogen.

Laboratory screening of fungicides will continue this winter. (A. A. Weathersbee, III, D. D. Hardee)

Field studies of *N. fresenii* spore dispersal will continue. While experiments this year dealt with identifying the location of dispersing spores, the proposed study will provide quantitative information useful in comparing spore density at different locations on the plant and within the field. This will be possible with computer image analysis which will allow captured images of spore deposition to be stored and then later analyzed for size, density, distribution, etc. (A. A. Weathersbee, III, D. D. Hardee)

Data will be collected for the second year in an effort to develop a regression equation useful in predicting the occurrence of *N. fresenii* epizootics in cotton aphid populations. Results of this year's efforts are pending analysis of these data this winter. The objective is to be able to predict an aphid population crash 7-10 days in advance by estimating the levels of several easily-obtained population parameters. (A. A. Weathersbee, III, D. D. Hardee)

Spray coverage evaluations and emergence cage tests will be carried out during and immediately following applications for the 1994 pilot test of *Heliothis zea* nuclear polyhedrosis virus. Replicated plots will be established along transects perpendicular to the application swath paths. Plots spaced at least one swath width apart along transects should be considered separate replications. Coverage will be monitored by placing water sensitive spray deposition cards and cotton leaves in each plot. Treated and protected seed heads from wild geranium will be collected from each plot. Deposition on spray cards will be evaluated by computer image analysis. Cotton leaves and geranium seed heads will be bioassayed for virus activity against laboratory reared budworm or bollworm larvae. Emergence cage tests will be conducted in each plot to determine the number and composition of moths emerging from treated vs. untreated (protected with plastic sheeting) areas. (A. A. Weathersbee, III, M. R. Bell)

2. Extramural

Research phase is completed on the Cooperative Agreement, "Color Indicator Method to Detect Nonoccluded Baculovirus in All Stages of *Microplitis croceipes*", and the program is extended for a one-year period with $5,000 additional funding to study the effects of *Microplitis croceipes* nonoccluded baculovirus on the tobacco budworm. (P. P. Sikorowski, J. L. Roberson)